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Evolutionary study of the Be star 28 Tau

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Abstract. We present an evolutionary study of 28 Tau, a Be star, in connection with its rapid rotation. The photometric data during the absence of its envelope in 1921 have been used to determine the effective temperature and luminosity of the star at the main sequence of the HR diagram. From an evolutionary model, we found that the mass and radius of the star are about 3.2 $M_\odot$ and 3.2 $R_\odot$ respectively. The equatorial rotation velocity of the star,ν_e found to be close to its critical velocity,ν_{cr} where $\nu_e/\nu_{cr} \simeq 0.87$.

Keywords. stars: fundamental parameters, stars: evolution, stars: rotation

1. Introduction

28 Tau (Pleione, BU Tau, HD 23862, HR 1180), a B8Vpe star (Hoffleit, 1995), is a well-known typical example of a Be star observed since the 18$^{\rm th}$ century. The variation of Be phases of 28 Tau has been reported since the early 19$^{\rm th}$ century until 2007 (Goraya *et al.*, 1990, Katahira *et al.*, 1996, Tanaka *et al.*, 2007). The hydrogen emission lines were absent for about 32 years and have returned in late 1938 as a noticeable emission line with a fine central reversal (McLaughlin, 1938). The absence of hydrogen emission lines – which indicate the destruction of the circumstellar matter - influences the measurement of the surface brightness of the star. In this study, photometric data during the absence of the envelope have been used to determine the effective temperature and luminosity of the star on the HR diagram. The evolutionary tracks were created using Eggleton code (Eggleton & Kiseleva-Eggleton 2002) with consideration of the star's rotation.

2. The evolutionary model

The evolutionary track has been created at specific mass and rotation, taking into account the dynamo activity, mass loss by dynamo-driven stellar wind and magnetic braking, and metallicity Z = 0.02. 28 Tau has been found to be a spectroscopic binary by Katahira *et al.* (1996) with the secondary star expected to be a low-mass helium star or white dwarf. He concluded that the circumstellar gas around the primary star is supplied by the primary itself, based on the mass-loss rate of its companion. Hence, in this study we only evolve 28 Tau as a single star. With an initial mass, $M = 3.2 M_\odot$ and rotational period, $P_{\rm rot} = 0.334$ days, we found the best approximated values with $\log T_{\rm eff} = 4.0359$ and $\log L = 2.1077$, based on photometric data during the absence of its envelope using the bolometric flux method (Gray, 1992) and the correlation of $T_{\rm eff}$ and BC (Flower, 1996). Table 2 shows the age in Myr, rotational velocity in km/s, critical velocity in km/s and the ratio of rotational and critical velocities of each model in Fig 1. Model 3 is an estimated position of 28 Tau on the HR diagram observed in 1921 where the ratio of

Table 1. The photometric data taken from Binnendijk (1949) only using photovisual and Pv method. The bold data were chosen for this study in obtaining the $T_{\rm eff}$ and L of 28 Tau.

Year	m$_v$	Met	Year	m$_v$	Met	Year	m$_v$	Met
1911	4.87±0.004	Pv	1914-1915	4.95±0.04	v	1928	5.00±0.06	Pv
1913	4.99±0.05	Pv	1916-1917	4.94±0.04	Pv	1931	4.96±0.06	Pv
1914-1915	4.92±0.03	Pv	**1921**	**4.85±0.03**	**Pv**	1936	5.04±0.04	Pg

Notes: Method : Pv-photovisual, v-visual and Pg-photographic

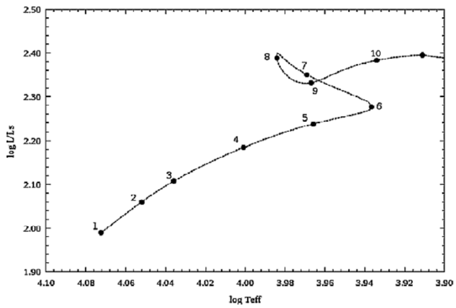

Figure 1. The evolutionary model of 28 Tau with initial M = 3.2M$_\odot$ and P$_{rot}$ = 0.334days.

Table 2. The values of age, P$_{rot}$(d), rotational velocity, ν, and critical velocity, ν_{cr}, at each model of the evolutionary track in Fig 1.

Model	Age	ν_e	ν_{cr}	ν_e/ν_{cr}	Model	Age	ν_e	ν_{cr}	ν_e/ν_{cr}
1	0.01	347.02	458.55	0.76	6	316.24	202.23	283.04	0.71
2	99.0	343.93	420.44	0.82	7	321.75	231.48	292.38	0.79
3	**154.73**	**341.26**	**394.01**	**0.87**	8	322.01	256.01	296.21	0.86
4	232.20	320.28	347.74	0.92	9	322.09	230.66	294.06	0.78
5	283.85	263.46	310.30	0.85	10	322.26	218.32	264.69	0.82

rotational to critical velocities is 0.87. The critical velocity is given by $\nu_{cr} = \sqrt{GM_\star/R_e} = \sqrt{2GM_\star/3R_p}$ where R_e and R_p are the radius at equator and pole respectively.

3. Result and discussion

The ratio of rotational velocity of 28 Tau to its critical velocity during the main sequence band has been calculated in the range of 0.71-0.92. The upper limit is close to the ratio by Townsend *et al.* (2004) i.e 0.95. From the models we suggest that the current mass of 28 Tau is 3.19 M$_\odot$, radius of 3.2 R$_\odot$ and rotational period is 0.475 days.

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